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Araştırma Makalesi

A Comparative Analysis of Factors Affecting the Selection of English Grammar Checkers with FUCOM and BWM

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Abstract
Online grammar checkers are interactive online software that offers authors suggestions to replace incorrect sentences with grammatically correct ones, repetitive words with alternative synonyms, and misspelled words with correct ones. Besides providing grammar checks to their users, also offer various services such as a dictionary, contextual guidance, similarity check, word/sentence suggestions, and punctuation correction. In addition to the basic services offered, users can also consider different criteria such as user-friendliness of grammar checkers, ease of installation, integration into different applications, customer service, reporting, and price, while choosing the most suitable software tool for their intended use. This study aims to determine and evaluate the factors that affect the selection of English grammar checkers. The prominent factors were evaluated by the users as an expert opinion and prioritized within themselves. In this evaluation stage, the results obtained were presented comparatively by applying the multi-criteria decision-making methods FUCOM and BWM.
Keywords: Grammar checker, natural language processing, multi-criteria decision-making, FUCOM, BWM
JEL Classification Codes: Z13, D91

İngilizce Dil Bilgisi Denetleyicilerinin Seçiminde Etkili Olan Faktörlerin FUCOM ve BWM ile Karşılaştırmalı Analizi

Öz
Çevrimiçi dil bilgisi denetleyicileri, hatalı yazılan cümleleri dil bilgisi açısından doğru olanlarla, tekrar eden kelimeleri eş anlamlı olan alternatif kelimelerle, yazım hatası içeren kelimeleri doğru olanlarla değiştirmek için yazarlara öneriler sunan interaktif çevrimiçi yazılımlardır. Bu araçlar, kullanıcılarına dil bilgisi kontrolü sağlamalarının yanı sıra, sözlük, bağlamsal rehberlik, benzerlik kontrolü, kelime/cümle önerileri, noktalama işaretlerinin düzeltilmesi gibi çeşitli hizmetler de sunmaktadır. Kullanıcılar, kullanım amaçlarına en uygun yazılım aracını tercih ederken sunulan temel hizmetlere ek olarak, dil bilgisi denetleyicilerinin kullanıcı dostu olması, kurulum kolaylığı, farklı uygulamalara entegre edilebilmesi, müşteri hizmetleri, raporlama ve fiyat gibi farklı kriterleri de dikkate alabilmektedir. Bu çalışmada İngilizce dil bilgisi denetleyicilerinin seçiminde ektili olan faktörlerin belirlenmesi ve değerlendirilmesi amaçlanmıştır. Öne çıkan faktörler, uzman görüşü niteliğinde kullanıcılar tarafından değerlendirilerek kendi içerisinde önceliklendirilmiştir. Bu değerlendirme aşamasında çok kriterli karar verme yöntemleri olan FUCOM ve BWM uygulanarak, elde edilen bulgular karşılaştırmalı olarak sunulmuştur.
Anahtar kelimeler: Dilbilgisi denetleyicisi, doğal dil işleme, çok kriterli karar verme, FUCOM, BWM
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1. Introduction

Language is a tool for individuals to express their thoughts, and feelings in their social life. It is a fundamental way for communication to share written or spoken forms of information (Bhirud, Bhavsar and Pawar, 2017, p. 2). English has an essential role in reaching the global (Lillis and Curry, 2010, p. 1). Especially, in academia, English is defined as *"the language of science"* (Drubin and Kellogg, 2012, p. 1399) and one can get a chance to become recognized if and only if publishing texts in English to reach a wide audience (Zakaria, 2022, p. 2). According to Web1, the most widely spoken language is English with 1132 million speakers which include 753 million non-native individuals. Namely, most people use English as a foreign language. Therefore, it is quite normal to expect errors in texts written by non-native authors (Soni and Thakur, 2018, p. 1). The possible errors can be classified as grammar and style (Thurmair, 1990, p. 365). The former which must be corrected includes punctuation, tense, vocabulary, misplacement (Bhirud et al., 2017, p. 3), preposition, spelling, and contextual (Soni and Thakur, 2018, p. 5) whereas the latter may be considered for better-formed sentences which are optional improvements (Thurmair, 1990, p. 365). For this reason, as stated by McKinley and Rose (2018), authors are willing to take an English language editing service to omit grammatical errors by a professional check. In order to ensure this control, native English speakers or publishers offer correction services to be charged according to the text size (Web2, Web3, Web4). However, the service received in this way both leaves the author out of the system and is much more costly in terms of time and economically.

According to Soni and Thakur (2018), automated grammar checkers would be beneficial for authors seeking new service channels for language editing. Grammar checking first emerged in the 1980s as a logical practice in which computers attempt to understand natural language (Bustamante and León, 1996, p. 1). The primary objective of language editing services which are grammar checking and correction are the major topics for Natural Language Processing (NLP) (Kumar and Nair, 2007, p. 348). Through the advancement in technology, the ability of computers has made breakthroughs, and modeling human language draws attention to the field of computational linguistics (Bhirud et al., 2017, p. 1). The advanced level of the approaches utilized by grammar checking tools affects the performance of the modeling. The techniques for grammar checking can be classified into three classes such as rule-based, machine learning-based, and hybrid. Rule-based approaches are traditional ways that utilize heuristic rules for approximate natural language grammar (Kumar and Nair, 2007, p. 348). However, mechanical support by itself becomes inefficient for individuals who expect intellectual assistance from machines (Bhirud et al., 2017, p. 4). Therefore, approaches such as machine learning and deep learning which are also known as corpus-based approaches become popular since they depend on statistical analysis for automated detection of grammar errors. In addition, in some cases, the combination of rule-based and

corpus-based approaches is required by considering their prominent features (Soni and Thakur, 2018, p. 9).

There are many similar grammar checker tools available today that use the aforementioned approaches. Although these approaches are the most essential issue affecting the performance of the tools, end-users may not have these details since they pay attention to different issues. Besides providing grammar checks to their users, they also offer various services such as the dictionary, contextual guidance, similarity checks, word/sentence suggestions, and punctuation correction. In addition to the services offered, different criteria such as user-friendliness of the tools, ease of installation, text reading, add-on features to different applications, customer service, performance reporting, or the price can also be effective for end-users.

Individuals need to evaluate many features to choose the most suitable grammar checker tool. Therefore, the evaluation of these various features is confronted as a multi-criteria decision-making (MCDM) problem. In MCDM problems, one of the main issues is the correct determination of the importance levels of the criteria that have a direct and great effect on the decision to be taken.

Therefore, this study mainly seeks an answer to a research question that examines the importance levels of the factors that affect the selection of English grammar checkers. As the second research question, it is examined whether BWM and FUCOM present different results in terms of determining the importance levels of the criteria.

Through this motivation for finding out the answers to these research questions, this study has two main objectives:

- Determination of the factors that are effective in the selection of leading English grammar checker tools in the market,
- Evaluation of the prominent factors by the users who are non-native speakers of English as an expert opinion.

The main way to establish effective written communication in the globalizing world is to use the English language correctly and effectively. Although English is a widely used language, most of the users have different mother tongues. Therefore, individuals are concerned about using the English language correctly. Artificial intelligence-based grammar checker tools help individuals to overcome these concerns. Through the developing technology, many grammar checker tools using different approaches are released to the market constantly. The fact that these tools have various outstanding features can affect the preferences of potential users. Therefore, MCDM problems related to grammar checker tools appear as an up-to-date research topic that needs to be addressed. In light of this information, it is aimed to provide a methodology that may support potential users in deciding on the appropriate grammar checker tools.

FUCOM and BWM, which are stand-out MCDM methods to obtain criteria weights with subjective evaluations, will be used to calculate and prioritize the weights of these factors, and a comparative analysis will be presented. These MCDM methods were preferred since they allow experts to make evaluations with fewer pairwise comparisons and accordingly offer ease of calculation. In addition, these methods stand out by providing consistent results due to fewer pairwise comparisons. Further specific advantages of each method will be provided in the methodology section.

Considering that grammar checker tools have just started to become widespread, to the best of our knowledge, there has not been a study that evaluates the criteria that are effective in the selection of grammar checker tools from the perspective of the end user. Moreover, no study addresses such a problem as an MCDM problem. Therefore, these facts form the basis of the novelty of the study. It is thought that this study will fill the gap in the literature, which will be discussed in more detail in the literature section.

The following parts of the study are structured as follows. The second section presents a comprehensive literature review, the third section explains the methodologies applied in this study, and the fourth section displays the application which includes factor details and the findings. Finally, the fifth section discusses the results and concludes the study.

2. Related Literature

The literature review is conducted in terms of both grammar checkers and the methodologies applied in this study. In the following subtitles, the literature related to grammar checker, FUCOM, and BWM are handled, respectively.

2.1. Grammar Checker Studies

In the literature, grammar checker tools are also named automated writing evaluation tools, proofreading tools, digital editing assistance tools, and online grammar platforms. In this study, the grammar checker term represents all of these concepts. The literature related to grammar checkers is based on either the language perspective or the methodology which is running in the background of the tools. However, the preferences of the users and the effective factors have key roles in deciding which grammar checker to be used. It would be good to briefly refer to the grammar checker studies that have been made so far.

The subject covered in our study is very up-to-date and includes today's technologies, however, it would be appropriate to mention the first steps taken. For instance, Macdonald (1983), Thurmair (1990), Genthial and Courtin (1992), Bustamante and León (1996), and Tschichold, Bodmer, Cornu, Grosjean, Grosjean, Ktibler, Lrwy and Tschumi (1997) presented grammar and style checker tools for

various languages. Although all these tools have lost their validity today, it can be said that they have pioneered the existing tools. Beyond traditional grammar checkers, in the light of technology and science, modern popular methodologies such as machine learning (Kumar and Nair, 2007) and deep learning (Tóth and Gosztolya, 2019), which are used for grammar checking, strengthen the existence of the tools used today.

Grammarly, PerfectIt, Linguix, Hemingway, ProWritingAid, Ginger, WhiteSmoke, and PaperRater are the top grammar checker tools utilized by many professionals (Web5, Web6, Web7). Studies focusing on these platforms have become a trend-topic, especially in recent years. Bhirud et al. (2017) reviewed grammar checking methodologies regardless of language. Yang (2018) handled a grammar checker tool called SpellCheckPlus in terms of feedback efficiency and students' perceptions. Soni and Thakur (2018) provided a systematic review including 12 studies questioning automated grammar checking tools for English. O'Neill and Russell (2019) investigated the perceptions of university students for Grammarly with an accompanying advisor. Gain, Rao and Bhat (2019) analyzed the satisfaction levels of Grammarly users in the Health Science Library. Parra and Calero (2019) conducted research to reveal the effect of grammar checker tools on the writing performances of students studying in the Department of English Language Teaching. John and Woll (2020) compared Grammarly, Virtual Writing Tutor, and Microsoft Word tools in terms of their automatic corrective performances. Barrot (2020), Calma, Cotronei-Baird and Chia (2022), and Thi and Nikolov (2022) reviewed the Grammarly platform technically and then recommended further enhancements. The performance differences of the students who use Grammarly were examined by Huang, Li and Taylor (2020) in China, by Dizon and Gayed (2021) in Japan, and by Sajjadpour (2021) in Iranian. Gautam and Jerripothula (2020) proposed a fake news detection tool by utilizing Spinbot, Grammarly, and GloVe tools. Ahmad, Mukhaiyar and Atmazaki (2022) reviewed Padlet, Kahoot, Youtube, Essaybot, and Grammarly tools for teaching essay writing courses in higher education. Tambunan, Andayani, Sari and Lubis (2022) examined the linguistic performances of Indonesian students by focusing on Grammarly as a tool. Kharis, Laksono and Suhartono (2022) investigated software that depends on Natural Language Processing (NLP) such as Google Translate, Grammarly, Quillbot, PoP, VOS-Viewer, Nvivo, and Elicit. Lamond and Cunningham (2022) compared editing assistance software programs such as Grammarly, Ginger, Microsoft Word, Google Docs, and Human raters by utilizing Woodcock-Johnson III Writing Samples.

As a result of a comprehensive review of grammar checking literature, it is seen that no conducted study focuses on the factors effective in the selection of grammar checker tools from the expert perspective. For this reason, it is thought that our study contributes to the literature in terms of grammar checking tool selection.

2.2. FUCOM Studies

The studies that applied FUCOM, and its extensions have been reviewed by considering the objective of the studies and their methodologies. A general evaluation of the studies and the gap in the literature is presented in the following.

Although FUCOM is a relatively new methodology, it is preferred for application in various fields. The literature was investigated by focusing on recently published and prominent studies. According to the studies, it is seen that sustainable supplier selection (Matić, Jovanović, Das, Zavadskas, Stević, Sremac and Marinković, 2019); (Ecer, 2021a); (Akar, 2022); location selection (Badi and Kridish, 2020); (Yazdani, Chatterjee, Pamucar and Chakraborty, 2020); (Ecer, 2021b); (Peker and Görener, 2022); performance evaluation (Cao, Esangbedo, Bai and Esangbedo, 2019); (Stević and Brković, 2020); (Hoan and Ha, 2021); (Pamucar, Ecer and Deveci, 2021); (Chakraborty, Sarkar and Chakraborty, 2022); (Özcan, 2022) are the main topics applied FUCOM in the literature. Besides, not only FUCOM but also its fuzzy extension is preferred and integrated with various MCDM methods. Furthermore, MARCOS (Stević and Brković, 2020); (Mitrović Simić, Stević, Zavadskas, Bogdanović, Subotić and Mardani, 2020); (Pamucar et al., 2021); (Blagojević, Kasalica, Stević, Tričkovič and Pavelkić, 2021); (Khosravi, Haqbin, Zare and Shojaei, 2022) is the most common methodology that is implemented together with FUCOM for various application field. Depending on the comprehensive literature review, the application of the FUCOM with BWM for product design is limited to the study conducted by Fazeli and Peng (2021). This comprehensive literature analysis points to the gap in the literature in the application area of FUCOM & BWM. Therefore, our study will contribute to the literature in terms of methodology.

2.3. BWM Studies

Studies utilizing BWM, and its extensions have been investigated. by considering the objective of the studies and their methodologies. Further evaluation of the studies is conducted in the following and consequently, we point out the gap in the literature.

The literature review was conducted including the prominent studies that implemented BWM. Green supplier selection (Tabatabaei, Amiri, Khatami Firouzabadi, Ghahremanloo, Keshavarz-Ghorabaee and Saparauskas, 2019); (Li, Xie, Cheng, Zhou and Fu, 2021); (Tavana, Shaabani, Santos-Arteaga and Valaei, 2021); (Çalık, 2021); sustainability (Çevik Aka, 2021); (Bilgiç, Torğul and Paksoy, 2021); (Wang, Lin and Wang, 2022); (Mendes, Ferreira, Kannan, Ferreira and Correia, 2022); COVID-19 (Qarnain, Sattanathan, Sankaranarayanan and Ali, 2020); (Ahmad, Hasan and Barbhuiya, 2021); (Öztaş, Bars, Genç and Erdem, 2022) stand out as topics apply BWM in the literature. In addition to classic BWM, fuzzy extension (Kumar, Mangla, Kumar and Song, 2021); (Irannezhad, Shokouhyar,

Ahmadi and Papageorgiou, 2021); (Lin, Ayed, Bouallegue, Tomaskova, Jafarzadeh Ghoushchi and Haseli, 2021); Z-number (Aboutorab, Saberi, Asadabadi, Hussain and Chang, 2018); Neutrosophic (Wang et al., 2022) integrations are preferred. Compared to FUCOM, scholars (Salimi and Rezaei, 2016); (Tabatabaei et al., 2019); (Wankhede and Vinodh, 2021); (Bazyar, Alipouri Sakha, Gordeev, Mousavi, Karmi, Maniei, Attari and Ranjbar, 2022); (Vieira, Ferreira, Govindan, Ferreira and Banaitis, 2022); (Mendes et al., 2022); (Öztaş et al., 2022); (Tavana, Mina and Santos-Arteaga, 2023) adopted BWM purely. According to the review, TOPSIS, COPRAS, and MULTIMOORA methods opted for integration with BWM.

A comprehensive literature review shows us that a comparative analysis including FUCOM and BWM has not been conducted in the field of grammar checkers for the English language. Therefore, it is thought that our study contributes to literature both in terms of the methodology and the field of application.

3. Methodology

In this study, the evaluation of the features that affect selecting grammar checkers is considered an MCDM problem. MCDM deals with problems in which alternatives are ranked or the best option within the set of alternatives is determined under various conflicting criteria. In these problems, the weight values expressing the importance of the criteria in the problem are the primary issues that affect the ranking or the result. The suitability of the approach adopted in determining the criteria weights will directly affect the success of the methodology used. For this reason, in this study, an analysis was conducted in light of the judgments of the decision-makers by using FUCOM and BWM, which are up-to-date methods in the literature, to evaluate the features of grammar checkers. The principles and steps of the MCDM methods used are presented respectively in the following sub-sections.

3.1. FUCOM

FUCOM is an MCDM method proposed by Pamučar Stević and Sremac (2018). FUCOM is preferred in cases where the criteria weights are determined by the subjective evaluations of the decision makers (DM) in an MCDM problem. The evaluations of DMs are based on pairwise comparisons. In this respect, FUCOM is similar to the prominent subjective decision-making methods, AHP (Saaty, 1977) and BWM (Rezaei, 2015). However, FUCOM requires only $n-1$ pairwise comparisons (Pamučar et al., 2018, p. 2). The increase in the number of pairwise comparisons needed with the increase in the number of criteria can cause problems in terms of the consistency of the evaluations (Ecer, 2021a, p. 25; Pamucar and Ecer, 2020, p. 420). Naturally, FUCOM will have an advantage over the aforementioned methods, as decision-makers who make minimal pairwise comparisons will have less *"mental workload"* and will reach the final judgment more quickly (Ocampo, 2022, p. 12489). This will also be a feature that prevents

the possible errors of decision-makers from occurring (Chakraborty et al., 2022, p. 6).

FUCOM finds the optimal values of these criteria with an optimization model to determine the weights of the criteria and measures the error of this model by calculating the degree of deviation from full consistency (DFC) (Pamučar et al., 2018, p. 5). It is deduced that the closer the value of DFC is to zero, the higher the reliability of the model results regarding the criteria weights (Ecer, 2021b, p. 33). In addition, there is mathematical transitivity in pairwise comparisons of criteria in FUCOM (Zagradjanin, Pamucar and Jovanovic, 2019, p. 8). In the light of this information, the application steps of the FUCOM method are as follows (Pamučar et al., 2018, p. 5-7):

Step 1: DMs rank the criteria in the $C = \{C_1, \dots, C_n\}$ criteria set from the most important to the least important according to their importance. The rankings of criteria are obtained given in Equation (1).

$$C_{j(1)} > C_{j(2)} > \cdots > C_{j(n)} \quad (1)$$

Step 2: A comparison of the ranked criteria is made. Then, the comparative priority of the evaluation criterion $\varphi_{k/(k+1)}$ (k stands for the rank of the criteria and $k = 1, 2, \dots, n$) is determined. The comparative priority of the evaluation criteria $\varphi_{k/(k+1)}$ expresses the advantage (importance) of the criterion $C_{j(k)}$ over the next criterion $C_{j(k+1)}$ in comparison. The comparative priority vectors of the evaluation criteria are obtained as in Equation (2).

$$\Phi = \left(\varphi_{1/2}, \varphi_{2/3}, \dots, \varphi_{k/(k+1)}\right) \quad (2)$$

Step 3: The final values of the weights of the evaluation criteria are calculated and must satisfy the following conditions:

Condition 1: The ratio of the weight values of the criteria should be equal to their comparative priority values as shown in Equation (3).

$$\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)} \quad (3)$$

Condition 2: In addition to *Condition 1*, criteria weights must satisfy the mathematical transitivity. This condition means that $\varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} = \varphi_{k/(k+2)}$. Using the mathematical transitivity property and Equation (3), we can write $\frac{w_k}{w_{k+1}} \otimes \frac{w_{k+1}}{w_{k+2}} = \frac{w_k}{w_{k+2}}$. In this case, the weight values of the evaluation criteria should satisfy the equality shown in Equation (4).

$$\frac{w_k}{w_{k+2}} = \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \quad (4)$$

If both conditions are met, full consistency is achieved, and the DFC (χ) value is equal to the minimum value of zero. The weight values of the criteria are obtained by solving the optimization model given in Equation (5).

$$\min \chi$$

$$s.t.$$

$$\left| \frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)} \right| \leq \chi, \forall j$$

$$\left| \frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \right| \leq \chi, \forall j \quad (5)$$

$$\sum_{j=1}^{n} w_j = 1$$

$$w_j \geq 0, \forall j$$

3.2. BWM

BWM is an MCDM method proposed by Rezaei (2015). BWM is used to determine criteria weights based on pairwise comparisons of decision-makers as in the AHP method. However, in the BWM method, pairwise comparisons are made by comparing the best and worst criteria determined by the decision-makers with all other criteria (Rezaei, Nispeling, Sarkis and Tavasszy, 2016, p. 581). Since comparison is made only according to the best and worst criteria, only $2n-3$ comparisons are needed compared to AHP (Rezaei, 2015, p. 51). If the number of pairwise comparisons required to make a final decision in an MCDM problem is large, decision-makers may make *"biasness and scattered decisions"* (Yadav, Luthra, Jakhar, Mangla and Rai, 2020, p. 6). At the same time, these unstructured comparisons can lead to inconsistency (Liu, Zhu and Wang, 2021, p. 2; Wan Ahmad, Rezaei, Sadaghiani and Tavasszy, 2017, p. 244). BWM, on the other hand, has a structured and easily understandable methodology that gives reliable results (Rezaei, van Roekel and Tavasszy, 2018, p. 159). The steps of the BWM method are as follows (Rezaei, 2015, p. 51-52):

Step 1: The criteria set (C) is generated and given in Equation (6), with the number of criteria being denoted by n.

$$C = \{C_1, C_2, \dots, C_n\} \tag{6}$$

Step 2: The best and worst criteria in the set C are determined.

Step 3: The best criterion is compared with all other criteria. The comparison is made with numbers in [1,9] interval. As a result of this comparison, the "*Best-to-Others"* vector (A_B) given in Equation (7) is obtained.

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn}) \tag{7}$$

Here, a_{BB} has a value of 1, which means the comparison of the best criterion with itself.

Step 4: Other all criteria are compared with the worst criterion. The same range of numbers as in the previous step is used in the comparison. The resulting "*Others-to-Worst"* (A_W) vector is as given in Equation (8).

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T \tag{8}$$

Here, a_{WW} equals 1, which shows the worst criterion being compared with itself.

Step 5: Optimal values of criteria weights (w^*) are calculated. These values are obtained by solving the optimization model given in Equation (9).

$$\begin{aligned} &\min \xi \\ &s.t. \\ &\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, \forall j \\ &\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi, \forall j \\ &\sum_{j=1}^{n} w_j = 1 \\ &w_j \geq 0, \forall j \end{aligned} \tag{9}$$

After solving the model, $w^* = (w_1^*, w_2^*, \dots, w_n^*)$ and ξ^* are obtained. Consistency measurement is essential in MCDM models. Rezaei, Wang and Tavasszy (2015) presented a consistency calculation for output based BWM models. However, in the case of linear BWM models, output-based consistency is not valid. Therefore, Liang, Brunelli and Rezaei (2020) developed model-independent input-based consistency measurement which provides immediate feedback to decision-makers. The calculation of the input-based consistency ratio (CR^I) is given in Equation (10-11).

$$CR^I = maxCR_j^I \tag{10}$$

$$CR_j^I = \begin{Bmatrix} \frac{|a_{Bj} * a_{jW} - a_{BW}|}{a_{BW} * a_{BW} - a_{BW}} & a_{BW} > 1 \\ 0 & a_{BW} = 1 \end{Bmatrix} \tag{11}$$

Liang et al. (2020) conducted Monte Carlo simulations to provide the threshold values for the appropriate consistency. According to these simulations, a threshold set is generated in terms of scale and the number of criteria in the related problem. For more information about threshold values for input-based consistency, the study conducted by Liang et al. (2020) can be checked. If an inconsistency is detected as a result of the calculation, decision-makers may be asked to review their evaluations (Yadav et al., 2020, p. 9).

4. Numerical Implication

4.1. Data

In the study, the criteria set was determined by examining the services offered by the leading grammar checkers to their users. Each grammar checker aims to reach more users by offering different features. For this reason, the features that are common in grammar checkers are as follows: *Grammar Check* (C_1) refers to presenting errors or suggestions by examining sentences in terms of grammar. *Plagiarism detection* (C_2) analyzes the written text in terms of similarity rate by comparing it with the texts found in databases. In texts such as scientific work or homework, the originality of the text is an important issue. *Contextual guidance* (C_3) analyzes the text with the help of artificial intelligence and examines the appropriateness of the words/terms used. *Reporting* (C_4) is reports and statistics that present information about usage, grammatical comparison with previous periods, and relative status to other users. *Price* (C_5) relates to the fee paid for subscribing to the service provided by the grammar checker. Some grammar checkers may also allow their users to have a limited experience with free plans. This situation may affect the preferences of decision-makers. *User-friendliness* (C_6) is related to the ease of use of the controller, accessibility, usability of its interface, etc. *Vocabulary/Sentence suggestions* (C_7) is the ability of the grammar checker to analyze the text and suggest the replacement of repetitive words with alternatives, replacement of inverted sentences or sentences written in a passive language with sequential sentences or active sentences. *Plug-in & Integration* (C_8) relates to tools that allow the controller to be used with a web browser, word processing, or other software products.

The features mentioned above which are effective in the selection of grammar checkers were evaluated by decision-makers with expertise in various fields. The characteristics of the decision-makers are given in Table 1.

Table 1: Decision-makers and Their Expertise

Decision Maker	Expertise Area	Professional Experience (years)	Education
DM_1	Optimization	9	Ph.D.
DM_2	Decision Making	9	Ph.D.
DM_3	Production Systems	7	Ph.D.
DM_4	Industrial Engineering	8	Ph.D.
DM_5	Business Administration	3	M.Sc.

4.2. Findings

The findings are presented in terms of both FUCOM and BWM respectively.

4.2.1. Findings of FUCOM

The steps detailed in Section 3.1 are followed when prioritizing decision-makers with FUCOM regarding the features of grammar checkers. The evaluations made by all decision-makers are given in Table 2.

Table 2: Evaluations of Decision-makers

DM_1	Ranking	$C_1 > C_3 > C_5 > C_7 > C_8 > C_6 > C_2 = C_4$							
	Criteria	C_1	C_3	C_5	C_7	C_8	C_6	C_2	C_4
	Degree of importance	1	2	3	4	5	6	9	9
DM_2	Ranking	$C_5 > C_1 = C_3 > C_7 > C_6 > C_8 > C_4 = C_2$							
	Criteria	C_5	C_1	C_3	C_7	C_6	C_8	C_4	C_2
	Degree of importance	1	2	2	4	5	6	8	8
DM_3	Ranking	$C_7 > C_5 > C_1 > C_2 = C_8 > C_6 > C_3 > C_4$							
	Criteria	C_7	C_5	C_1	C_2	C_8	C_6	C_3	C_4
	Degree of importance	1	2	3	4	4	5	6	7
DM_4	Ranking	$C_3 > C_7 > C_1 > C_4 > C_2 > C_6 > C_5 > C_8$							
	Criteria	C_3	C_7	C_1	C_4	C_2	C_6	C_5	C_8
	Degree of importance	1	2	3	4	6	7	8	9
DM_5	Ranking	$C_1 > C_7 = C_8 > C_3 > C_6 > C_4 > C_2 > C_5$							
	Criteria	C_1	C_7	C_8	C_3	C_6	C_4	C_2	C_5
	Degree of importance	1	2	2	3	4	6	7	9

The weights of the criteria are reached by solving the optimization model, which was created based on the evaluations of DM_1 and whose general structure is given in Equation (5). This process, which was explained for DM_1, was applied separately for all decision-makers, and criteria values were obtained based on the evaluations by solving optimization models. The criteria weights obtained for each decision maker are given in Table 3.

Table 3: Criteria Weights Obtained with FUCOM

	$C_1(w_1)$	$C_2(w_2)$	$C_3(w_3)$	$C_4(w_4)$	$C_5(w_5)$	$C_6(w_6)$	$C_7(w_7)$	$C_8(w_8)$
DM_1	0.3742	0.0416	0.1871	0.0416	0.1247	0.0624	0.0936	0.0748
DM_2	0.1744	0.0436	0.1744	0.0436	0.3488	0.0698	0.0872	0.0581
DM_3	0.1173	0.0879	0.0586	0.0503	0.1759	0.0704	0.3518	0.0879
DM_4	0.1268	0.0634	0.3804	0.0951	0.0475	0.0543	0.1902	0.0423
DM_5	0.3329	0.0476	0.1110	0.0555	0.0370	0.0832	0.1664	0.1664
Average	**0.2251**	**0.0568**	**0.1823**	**0.0572**	**0.1468**	**0.068**	**0.1778**	**0.0859**

When the last line in Table 3, which includes the average values, is examined, it is seen that the weight of w_1 of the *Grammar check (C_1)* criterion is the most important criterion for decision makers with a value of 0.2251. According to the degree of importance for the decision-makers, this criterion is followed by the weights w_3 and w_7, which have the values of the *Contextual guidance (C_3)* and *Vocabulary/Sentence suggestions (C_7)* criteria. The values of these weights are 0.1823 and 0.1778, respectively. *User-friendliness (C_6)* ($w_6 = 0.068$), *Reporting (C_4)* ($w_4 = 0.0572$) and *Plagiarism detection (C_2)* ($w_2 = 0.0568$) were determined as the three criteria with the least importance for decision-makers, respectively. The obtained values indicate that the basic functions expected from a grammar checker are more important for decision-makers while the interface, usage statistics, and similarity ratio comparison are less important.

4.2.2. Findings of BWM

According to the steps explained under the title of 3.2. BWM, firstly all DMs determined *"the best"* and *"the worst"* criteria among the criteria set. The best criterion for each DM is presented in bold in Table 4. Thereafter, as stated in Equation (7) all DM structured Best-to-others vectors by considering a 1-9 scale.

Table 4: Best-to-Others

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
DM1	**1**	9	2	9	3	6	4	5
DM2	2	8	2	8	**1**	5	4	6
DM3	3	4	6	7	2	5	**1**	4
DM4	3	6	**1**	4	8	7	2	9
DM5	**1**	7	3	6	9	4	2	2

As stated in Equation (8), all DMs structured Others-to-worst vectors by considering the 1-9 scale as well. The worst criterion determined by all DMs can be seen in bold in Table 5.

Table 5: Others-to-Worst

	DM1	DM2	DM3	DM4	DM5
C_1	9	7	6	7	9
C_2	**1**	**1**	5	4	3
C_3	8	7	2	9	7
C_4	**1**	**1**	**1**	6	4
C_5	7	8	7	2	**1**
C_6	4	4	4	3	6
C_7	6	5	8	8	8
C_8	5	3	5	**1**	8

Tables 4 and 5 include the evaluations of DMs which can be defined as the inputs of BWM. In the light of the evaluation vectors of each DM, the weights of criteria were calculated by utilizing BWM-Solver provided in Web8. The weights are given in Tables 6.

Table 6: Criteria Weights Obtained with BWM

	$C_1(w_1)$	$C_2(w_2)$	$C_3(w_3)$	$C_4(w_4)$	$C_5(w_5)$	$C_6(w_6)$	$C_7(w_7)$	$C_8(w_8)$
DM_1	0.3347	0.0291	0.2038	0.0453	0.1358	0.0679	0.1019	0.0815
DM_2	0.1881	0.0313	0.1881	0.0470	0.3135	0.0752	0.0940	0.0627
DM_3	0.1285	0.0963	0.0642	0.0338	0.1927	0.0771	0.3110	0.0963
DM_4	0.1383	0.0691	0.3407	0.1037	0.0519	0.0593	0.2074	0.0296
DM_5	0.2949	0.0513	0.1197	0.0598	0.0256	0.0897	0.1795	0.1795
Average	**0.2169**	**0.0554**	**0.1833**	**0.0579**	**0.1439**	**0.0738**	**0.1788**	**0.0899**

When the last line in Table 6, which includes the average values, is examined, it is seen that the weight of w_1 of the *Grammar check (C_1)* criterion is the most important criterion for decision makers with a value of 0.2169. According to the degree of importance for the decision-makers, this criterion is followed by the weights w_3

and w_7, which have the values of the *Contextual guidance (C_3)* and *Vocabulary/Sentence suggestions (C_7)* criteria. The values of these weights are 0.1833 and 0.1778, respectively. *User-friendliness (C_6)* ($w_6 = 0.0738$), *Reporting (C_4)* ($w_4 = 0.0579$) and *Plagiarism detection (C_2)* ($w_2 = 0.0554$) were determined as the three criteria with the least importance for decision-makers, respectively. The obtained values indicate that the basic functions expected from a grammar checker are more important for decision-makers while the interface, usage statistics, and similarity ratio comparison are less important. The consistency measurements for each DM evaluation were calculated via BWM-Solver as (0.2222, 0.2143, 0.3095, 0.2083, 0.2083) respectively. According to the consistent threshold for a nine scale with eight criteria which is 0.3620, it is concluded that all evaluations are consistent.

4.2.3. Comparative Analysis

The results of the FUCOM and BWM methods can be compared. Aggregated criterion weights were used to compare the results obtained by both methods. Aggregated criterion weights were obtained by arithmetic averages of the values in the relevant tables.

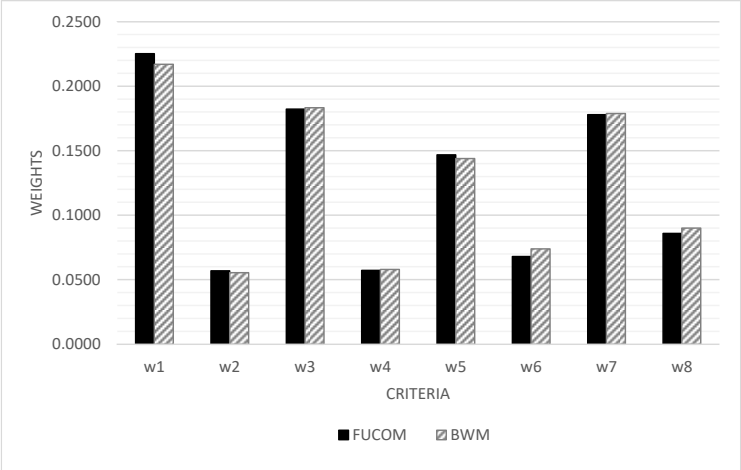

Figure 1: Comparison of FUCOM & BWM Methods

Figure 1 shows that the criterion weights obtained by both methods are very close to each other. When the differences between the criteria weights obtained by the methods are examined, it is seen that the biggest differences are between 0.008 for w_1 and 0.006 for w_6. As a result of the fact that both methods give very close results, the correlation between the criteria weights obtained is calculated as 0.9986. This result shows that FUCOM and BWM methods are coherent.

This result is not surprising since the working principles of the two methods are similar. However, the fact that decision-makers make much fewer comparisons in the FUCOM method shows the superiority of the FUCOM method over BWM.

5. Discussion and Conclusion

In this study, a topic that is essential for individuals who use English as a foreign language was handled. Firstly, the literature was reviewed comprehensively to reveal the factors that may be effective in the selection of grammar checker tools. However, there is no study providing this information sufficiently. Therefore, the tools developed for grammar checkers were investigated and their prominent features were disclosed. Secondly, five decision-makers from various expertise areas were included in the study to evaluate the factors. The weights of criteria were calculated with FUCOM and BWM by considering the evaluations of decision-makers. Lastly, the findings of these two MCDM methodologies were compared and discussed.

According to the results, the grammar check feature has come to the fore as an effective factor in the selection of grammar checker tools. In addition, the least important feature was Plagiarism detection for both methods. This finding is not surprising. Grammar check comes to the fore as the main task of grammar checker tools. In addition to this feature, plagiarism detection took the last place as a reason for preference due to being one of its side roles. This can be explained by the existence of specially developed tools for plagiarism detection. As a result of the similarity of the two methods, the ranking of the criteria was obtained as the same. However, there are negligible differences in criterion weights. When other factors that are effective in the selection of grammar checker tools were examined, it was seen that the contextual guidance feature was more important than the vocabulary/sentence suggestion. This shows that the confirmation of the accuracy of the written text, both grammatically and conceptually, is more important than the word/sentence suggestions for individuals. The low level of importance of the user-friendly feature can be considered a surprising result. Similarly, the reporting criterion was obtained as a less important feature. Another surprising result is that the price criterion is not prioritized. It can be interpreted that the decision-makers will not prioritize the price as long as the tool fulfills its main roles. As a general evaluation, it is seen that the criteria were placed in three different categories. In the first group, the features that are the main roles of these tools were listed, in the second group the price, and finally, the additional features of these tools were grouped.

As a result of this study, the evaluations of the decision-makers indicate to the software developers that the side features are not very effective in the choice, while the further strengthening and differentiation of the algorithms working in the background for the main task of grammar control will play an active role in the selection of tools. In addition, this study can be considered a guide for researchers/writers whose native language is not English. The limited number of studies in literature dealing with tools developed for grammar control and the lack

of studies evaluating grammar checkers with MCDM tools make our study stand out and contribute to the literature.

The limitations of the study should also be mentioned. The findings reflect only the individual experiences of the decision-makers. This study is not aimed at obtaining a result that represents the opinion of a community. Only expert opinions as users were evaluated. In addition, the criteria that are effective in the selection of grammar checker tools are limited to the common features of the tools used in practice.

In further studies, inferences can be made with statistical analyzes with a large audience using grammar checker tools. Experts from different nations, as decision-makers, can evaluate the criteria and reveal the differences. The study can be reconducted with new features when software developers release grammar checkers with various features. By reaching individuals who actively use the main grammar checker tools used in the market and have full knowledge of all their features, the study can also be discussed in terms of grading the alternatives.

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